Congressional Report
On The
National Aerospace Initiative

In Response to the
Senate Armed Services Committee Report
Accompanying the
National Defense Authorization Act
For Fiscal Year 2004
(S. R. 108-46)

September 2003

Preface

The Senate report accompanying the National Defense Authorization Act For Fiscal Year 2004 (S. R. 108-46) requested that the Director of Defense Research and Engineering (DDR&E) submit a report on the National Aerospace Initiative (NAI). Specifically, the report stated:

> ***The committee agrees with the National Aerospace Initiative (NAI) goals and the three supporting pillars of this program: high-speed hypersonics; access to space; and space technology. The committee is concerned, however, that the NAI program is based on an artificial schedule rather than realistic assessments of the technological developments and capabilities necessary to achieve the goals of the program. The success of NAI appears to rely upon the successful technology demonstrations within current and future programs rather than the supporting revolutionary scientific and technological discoveries that will be necessary to meet the ambitious goals of the Initiative. The committee remains concerned about whether there are adequate investments in the basic and applied research, which are necessary for the technologies needed to reach the goals of NAI. Therefore, the committee directs the Director of Defense Research and Engineering (DDR&E) to submit a report to the congressional defense committees by September 1, 2003, outlining the technology roadmap and capability requirements, including basic research activities, necessary to achieve the NAI goals. The report should include current and future investments in the enabling technologies necessary to reach the goals of NAI.***

In response to this request, the Department of Defense (DoD) and National Aeronautics and Space Administration (NASA) convened a team to prepare this report. The NAI technology plan addresses capability requirements, provides a balanced and integrated technology roadmap, and outlines the requisite investments to enable critical military capabilities.

While both the DoD and NASA need to overcome the critical technical barriers of high-speed/hypersonic flight, space access, and advanced space technology, this report emphasizes the benefits of the NAI to the DoD.

Introduction

Aerospace capabilities helped shape the 20th century, transforming our warfighting capabilities and propelling the U.S. to the forefront of space-faring nations. Our nation has depended on the aerospace sector for decades to ensure America's leadership in the world of high technology – including the manufacturing of military and commercial aircraft, satellites, space launch vehicles, weapon systems, and telecommunications systems (Reference 1).

Today, our military is unquestionably the best in the world. As we demonstrated in the Persian Gulf, Kosovo, Afghanistan, and recently in Iraq, our aerospace capabilities are critical to international security and underwrite the capabilities of allied coalitions with whom we are involved in the vital work of maintaining international peace and security. Space-based applications, such as the Global Positioning System (GPS), now provide us precision information to help identify, locate, and prosecute military targets.

Looking ahead, the world is rapidly changing. Key among these changes are significant shifts in the global threat including increased numbers of satellites with military capabilities, to advanced cruise and ballistic missiles, to Weapons of Mass Destruction (WMD's). We must address potential threats to our space assets including ground stations, launch systems, or satellites on orbit. This problem is more serious for the U.S. because of our greater dependency on space than any other nation

Future adversaries will undoubtedly be more mobile and agile, often presenting only fleeting targets. In order to successfully execute a strike, the time to locate, identify, and target (i.e., decision time) plus the time to deliver a weapon to target (i.e., flight time) must be within the availability time of the target; i.e.,

$$\text{Time}_{\text{Decision}} + \text{Time}_{\text{Flight}} < \text{Time}_{\text{Target Availability}}$$

Rapid advances in intelligence, surveillance, and reconnaissance (ISR) together with data fusion and decision tools have made tremendous reductions in decision times and progress in target availability. The limiting factor in many situations is now the flight time to deliver a weapon to target. High-speed/hypersonic[1] weapons systems offer order-of-magnitude reductions in flight time. The combination of reduced decision time and flight time could now improve the potential to bring the kill chain within the window of target availability for time critical targets. As an example, from a range of five-hundred miles away, a hypersonic weapon system traveling at Mach 6 could have struck its target in 7 minutes in the recent Iraqi conflict – approximately 9 times faster than the conventional Tomahawk cruise missiles that were employed. Hypersonic technologies available to our military on that day may have had a markedly different outcome. Other detailed examples highlighting the value of speed in today's warfare environment are available on request.

We face challenges from international competitors. Sustained, long-term investments in aerospace research and development are building foreign expertise and experience in hypersonic

[1] Hypersonic flight is defined as flight at speeds greater than Mach 4

technologies. Foreign ground test facilities are, in many cases, the best in the world; and Australia, France, Germany, India, and, Russia all have acknowledged high-speed/hypersonic programs. China has claimed a hypersonic aircraft development program with a technology availability date of 2015. It is clear from these acknowledgments that the international community is committing to long term investments in high-speed/hypersonics research.

In its report to the President and Congress (Reference 1), *The Commission on the Future of the United States Aerospace Industry* recommended that our nation boldly pioneer new frontiers in aerospace technology, commerce, and exploration, and endorsed the joint NAI partnership between DoD and NASA to make revolutionary advances in high-speed/hypersonic flight, space access, and space technology.

The NAI is an integrated, nationally planned and executed science and technology (S&T) development and demonstration initiative focused on solving and demonstrating the fundamental physics associated with advanced high-speed/hypersonic airbreathing systems, advanced rocket systems, and space-based payloads – offering a truly revolutionary advancement in warfighting capability and our ability to utilize space. The NAI leverages and culminates decades of government investment in these technology areas through a series of ground and flight demonstrations[2] aimed at transitioning these technologies toward operational use while continuing to advance the basic technology in these areas. The NAI goals are challenging, yet achievable, and the leap-ahead capabilities provided through this initiative could be critical to U.S. national security.

[2] "Flight demonstration" in this report refers to both flight test and flight demonstration activities.

Capability Requirements

The Secretary of Defense's (SECDEF) *Quadrennial Defense Review (QDR) Report* (Reference 2) submitted to Congress in September 2001 identified six transformational operational goals: Protect Bases of Operation, Assure Access to Information Systems, Project and Sustain U.S. Forces, Deny Enemies Sanctuary, Enhance the Capability and Survivability of Space Systems, and Leverage Information Technology. In the Deputy SECDEF-directed report, *Linking Science & Technology to Transformation* (Reference 3), it states (1) "interim development of hypersonic flight will lead to a new class of highly destructive weapons and missiles simply through kinetic energy"; (2) **"**Increased platform speed can be applied to time critical targets, missile defense, and strike options consistent with the Nuclear Posture Review; as well as a potential first stage of a reusable launch vehicle"; (3) "hypersonic flight could lead to more responsive access to space; which supports the ability to continue to dominate space with more capable, lighter weight, more durable space platforms"; (4) "…the U.S. could have the capability to launch a group of micro satellites into any orbital location, and align them to provide on-demand high resolution optical and radar surveillance"; and (5) "[this technology] … provides a high potential to be transformative in several ways, and could provide a dramatic increase in speed, agility, lethality, knowledge, and survivability."

There are strong NAI linkages to a number of long-standing Joint Requirements Oversight Council (JROC) requirements, as well as to the needs of long range strike – including the need for high-speed penetrating weapons, hypersonic missiles, supersonic cruise/hypersonic dash vehicles, and a Common Aero Vehicle. Common key technologies include a number of propulsion options (such as fuel-efficient expendable turbine engines, high-speed turbines for acceleration and cruise, and durable ramjet/scramjet/combined cycle propulsion systems); advanced high lift-to-drag airframes; and high temperature thermal protection systems.

The *Nuclear Posture Review* (Reference 4) identified a number of future system requirements that could benefit from the military capabilities NAI will provide, including the need for follow-on air-launched and sub-surface-launched cruise missiles, intercontinental and sub-surface-launched ballistic missiles, and a replacement heavy bomber. In July 2002, President Bush signed Unified Command Plan (UCP) Change 1, which merged U.S. Strategic Command and Space Command under the U.S. Strategic Command Combatant Commander; and in January 2003, he signed UCP Change 2 giving U.S. Strategic Command several new mission assignments which included global strike; information operations; integrated missile defense; and global Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR). NAI is directly responsive to a number of these new mission assignments for Strategic Command. In its *America's Air Force: Global Vigilance, Reach and Power, Joint Vision 2020* (Reference 5), the Air Force states its desire for "…controlling and exploiting the full aerospace continuum"; and in its Scientific Advisory Board Study, *Why and Whither Hypersonics Research in the US Air Force,* (Reference 6) states "This (responsive space access) will be a critical enabler for making the Air Force vision a reality, as hypersonics could be the next great step in the transformation of the Air Force into a completely integrated *aerospace* force." Within these contexts, the three NAI pillars of high-speed/hypersonics, space access, and space technology have a direct and measurable connection to a broad spectrum of user requirements.

The 1998 National Research Council (NRC) Committee on Review and Evaluation of the Air Force Hypersonic Technology (Reference 7) concluded that "For 2015 and beyond, the Air Force should pursue the evolutionary development of hypersonic weapon systems and develop a long-range plan that incorporates the following four components: operational concepts for future systems and preliminary systems designs; scramjet-powered weapon systems using hydrocarbon fuels; hypersonic weapons using hydrogen fuels; and combined-cycle systems for space access." In particular, Air Force programs to develop a hydrocarbon supersonic combustion ramjet (the HyTech program) if "expanded to include full-scale, integrated airframe-engine flight test program, and if critical enabling technologies were mature, an operational air-breathing hypersonic missile system could be developed with low-to-moderate risk…in support of an initial operational capability by 2015."

Additionally, the DoD and NASA completed a joint "120-Day" study (Reference 8) whose objective was to develop a credible, comprehensive plan for a joint NASA-US Air Force (USAF) development of the next generations of reusable launch vehicles (RLV) that meets NASA and USAF access-to-space requirements. This study complements NASA's new Integrated Space Transportation Plan (ISTP), which identifies the need to develop a next generation of launch systems with short term focus on rocket propulsion technologies while simultaneously pursuing hypersonic airbreathing technology to develop fully reusable, reliable launch systems.

The national security aspects of the NAI are clear and the benefits are recognized by many key military leaders, such as Admiral Ellis, the U.S. Strategic Command Combatant Commander. In testimony to the Senate Armed Service Committee, Ellis said, "We believe that by partnering closely with … the <u>National Aerospace Initiative</u> … these advanced conventional capabilities will be an increasingly significant part of the planning and capabilities that fall under our purview. They're <u>absolutely essential for our future</u>. They were a part of the assumptions that were implicit in the nuclear posture review and we certainly appreciate your support of these efforts to develop such capabilities." They were also acknowledged by Brigadier General Zilmer, Headquarters, U.S. Marine Corps, who testified to the Senate Subcommittee on Science, Technology, and Space that "The USMC has also made an effort to make the Small Unit Space Transport and Insertion (SUSTAIN) need a user-pull foundation piece of the National Aerospace Initiative." The compendium of operational requirements studies, technology assessments, joint-planning efforts, and breakthroughs in research from past and on-going programs point to the need for a multi-agency, integrated national approach.

There is now an opportunity for the nation to develop a new generation of aerospace capabilities for our national defense, economic competitiveness, and quality of life. Previously, numerous programs have been undertaken by the DoD and NASA in an attempt to realize these potential benefits. Examples include, joint DoD-NASA National Aerospace Plane (NASP), NASA's X-33, X-34, X-37, X-38 and the DARPA Affordable Rapid Response Missile Demo (ARRMD). While some of these previous programs were unsuccessful at achieving their desired end goals, each made significant advances in the fundamental technology.

This nation has invested almost $5B over the past forty years in high-speed/hypersonics technology. Significant advances have been made in many technologies, such as high temperature materials, light weight composite tanks, flow physics and component databases, detailed vehicle level aerodynamic and aerothermal databases, propulsion databases for Mach 0-15+, validated vehicle/engine design methods, and conceptual designs of effective vehicles. For example, over two-hundred full-scale ground tests have been accomplished on four different propulsion systems at various U.S. wind tunnels over the past two years. We have yet to execute a flight test program to demonstrate these technologies. Basic and applied research in these technologies must continue, but we must take the next step of flight demonstration to validate theoretical work, inform and focus future research activities, and transition these technologies to operational use. We need to reap the benefits of our investment and address the needs of the 21st century – it is now time to fly!

NAI Technology Roadmaps

The NAI Technology Roadmaps in the three focused pillars of High-speed/Hypersonics (HS/H), Space Access (SA), and Space Technology (ST), shown in Figure 1 below, were created through a series of workshops convened by the DoD/NASA NAI team. Inputs were solicited from our nation's government, industry, and academia experts, including representatives from the U.S. engine and aerospace vehicle companies, the National Research Council, a number of universities, and the JASONs. These NAI Technology roadmaps provide the framework for technically integrating existing and new research and engineering programs, projects, and activities funded and executed individually and/or jointly by the Army, Navy, Air Force, DARPA, and NASA, which when viewed collectively, achieve the NAI national goals in the three pillar areas.

To accomplish the NAI goals, a balanced investment portfolio from basic research to technology demonstration is essential. For example, the University Research, Engineering, and Technology Institutes (URETI) are conducting basic and fundamental research in support of the NAI. Both the University of Maryland and Georgia Institute of Technology, along with their partners, are now jointly sponsored by DoD and NASA through the URETI program, which began in the fall of 2002. Technology demonstrations are now focused on demonstrating technologies in the relevant operating environment (ground, flight, or space) necessary for transition to next generation systems.

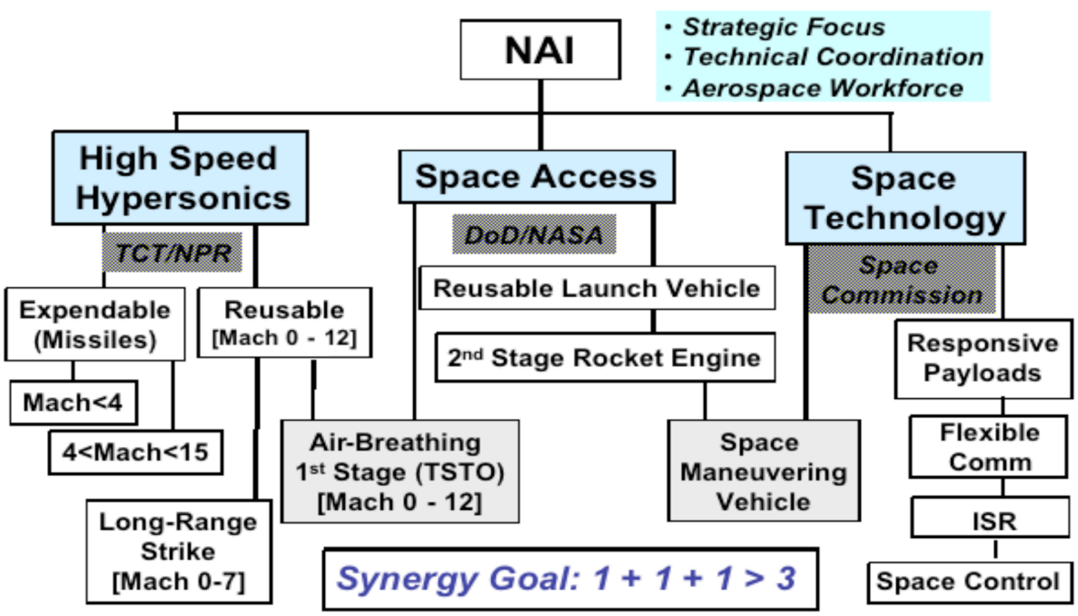

Figure 1
NAI Technology Framework
(TCT/NPR – Time Critical Targets/Nuclear Posture Review, Space Commission – Commission to Assess United States National Security Space Management and Organization)

The HS/H pillar is focused on providing revolutionary technology advancements for HS/H strike weapons, high-speed cruise vehicles, and airbreathing first-stage systems for space access. Over forty years of continuous U.S. technology development, with successful ground tests of HS/H concepts – including propulsion, aerodynamic and aerothermal, structural and flow physics – form the hypersonic technology foundation. NAI leverages technological advances from such highly successful on-going programs as the Integrated High Performance Turbine Engine Technology (IHPTET) program. Through a combined government/industry investment of over $4B since 1988, IHPTET has advanced turbine engine technology with the goal of doubling propulsion system performance. In so doing, it has provided multiple ground tests of compact, light weight Mach 3-4 low-cost turbojets that have application in the HS/H arena. Other NAI-related activities have successfully demonstrated nearly one-hundred tests from Mach 3.5 – 6.5 of a dual combustor ramjet; over thirty runs on the first flight-weight, fuel-cooled hydrocarbon scramjet; and, in 2002, over seventy hydrogen-fueled scramjet tests at Mach 10 and twenty tests at Mach 12 in Army shock tunnel testing. The HS/H roadmap continues to develop and mature key HS/H technologies.

The HS/H pillar addresses both propulsion elements (such as turbojets, ramjets, dual-mode scramjets and combined cycle engines) and airframe elements (such as configuration aerodynamics, stability and control, and high temperature structural concepts). The top-level HS/H pillar technology roadmap is shown in Figure 2. A continuous flow of basic and applied research feeds the HS/H technology demonstrations that, in a stepping-stone approach, provide increasing military capabilities through achievement of the NAI goals. Detailed technical objectives for the HS/H pillar are available on request.

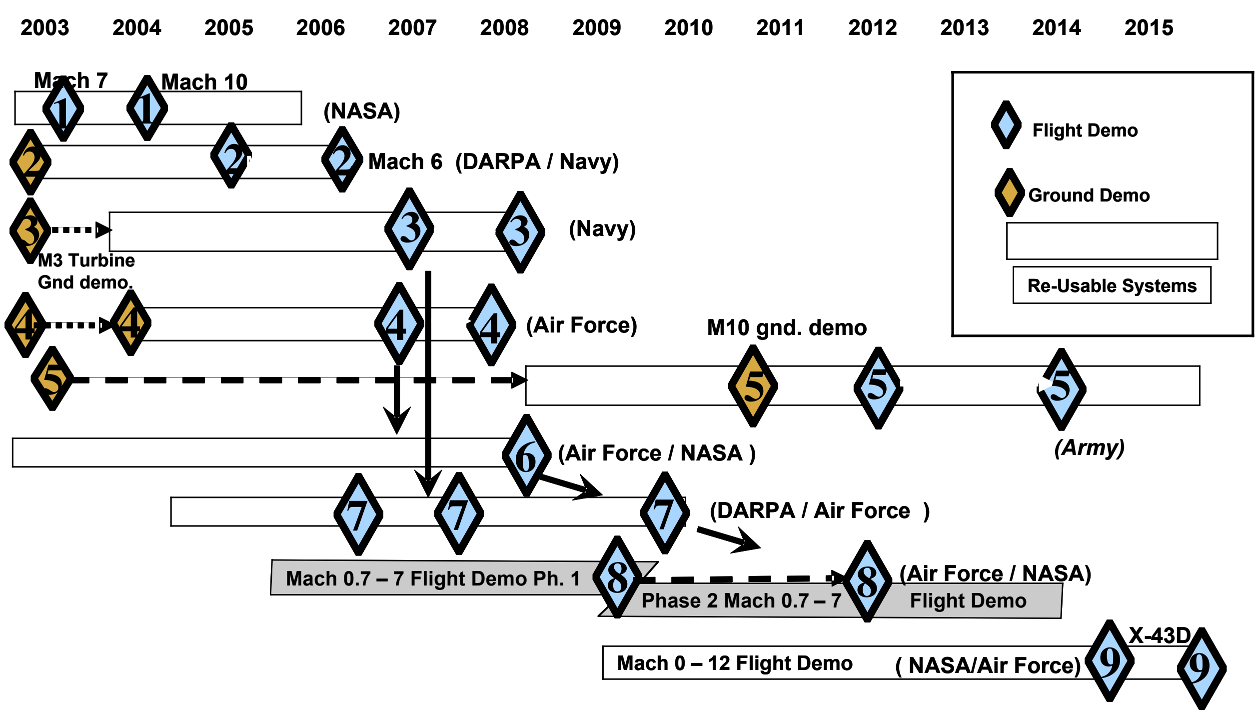

Figure 2
High-speed/Hypersonics (HS/H) Technology Demonstration Roadmap
(FY)

HS/H technology developments will culminate in a series of flight demonstrations that can provide near-term transition off-ramps to operational capabilities. Figure 3 shows potential capability off-ramps that are a direct result of these technology demonstrations.

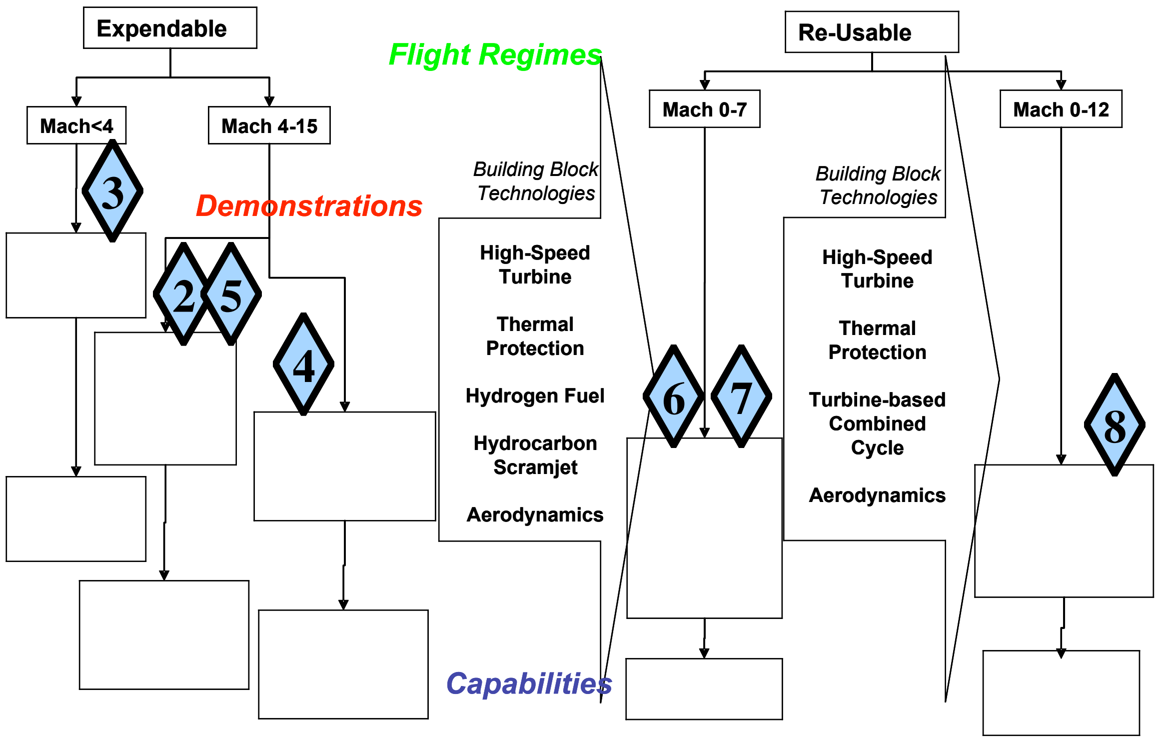

Figure 3
High-speed/Hypersonics (HS/H) Capability Off-ramps

The SA pillar is focused on developing and demonstrating advanced technologies that can enable future spacelift systems to be more affordable, responsive, safe, and flexible. SA technology goals support both the Air Force Space Command pursuit of a Military Space Plane and NASA needs for both a Shuttle replacement and new capabilities for space exploration beyond low earth orbit. The SA technology thrusts address the technical challenges associated with both hydrogen- and hydrocarbon-fueled main engines; large integrated structures and cryogenic tanks; thermal protection systems; and efficiency improvements derived from integrated health management and advances in range and ground operations.

The SA program uses a balanced approach of basic and applied research, coupled with advanced technology demonstrations, to provide adequate validation of the NAI goals. This approach progressively advances technologies from sub-scale research into major subsystems and systems for test in a relevant environment. This testing in a relevant environment is essential for transition of the technology base. While many SA technologies can be tested on the ground, those that cannot – due to our inability to simulate realistic environments in ground test facilities (e.g., thermal protection system, leading edges, and some integrated systems) – must be tested on

X-vehicles or in small flight experiments. The basic research activities, including universities around the country and the world, provide the foundation for these demonstrations. The SA roadmap highlights the major technology testbeds and demonstrators needed to provide verification in a relevant environment (ground, flight, or space), which is normally sufficient to proceed into system development or system upgrade. For example, the Falcon program contributes lower cost boosters (Operationally Responsive Spacecraft) and a Common Aero Vehicle development. The SA pillar technology roadmap is shown in Figure 4. Detailed technical objectives for the SA pillar are available on request.

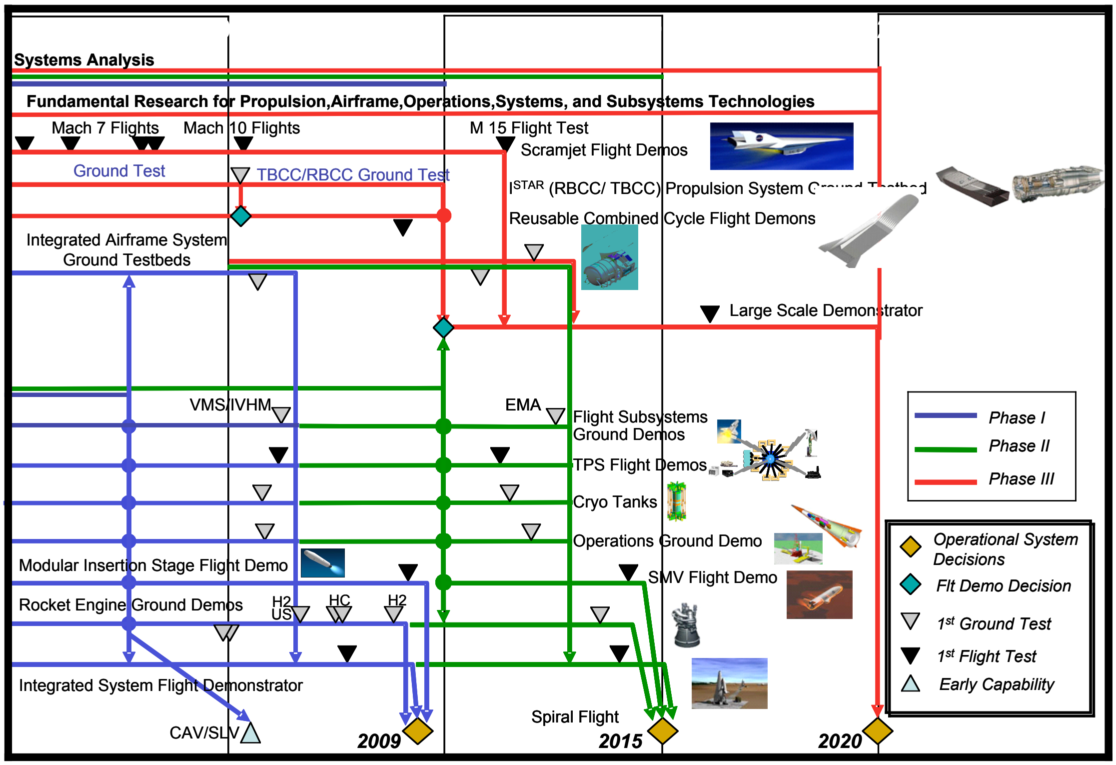

Figure 4
Space Access (SA) Technology Roadmap
(FY)

The ST pillar focuses on developing and demonstrating a portfolio of critical technologies that can enable achievement of space situational awareness, defense of space systems, rapid deployment/employment of military payloads, persistent global ISR, and robust global communication – providing necessary and sufficient information anywhere, anytime. Demonstration of these technologies will provide the DoD with transformational capabilities never-before available to the warfighter.

The ST pillar develops and exploits advances in multiple technologies relating to sensors (hyperspectral/multispectral electro-optic/infrared); synthetic aperture and laser radars; large antennae; signal/image processing; sensor fusion; information fusion; programmable/anti-jam transceivers; and laser communications. The ST pillar also places high emphasis on responsive payload technology demonstrations in support of transformational communications architectures, future ISR architectures, and space control architectures. This technology will address: low-out-gassing materials; autonomous check-out/anomaly resolution; standard interfaces for sensors and boosters; rapid on-orbit check-out capability; bi-static engagement; high-efficiency, space-based, electric lasers; and predictive space situational awareness for monitoring/protecting space assets. The ST pillar technology roadmap is shown in Figure 5**.** Detailed technical objectives for the ST pillar are available on request.

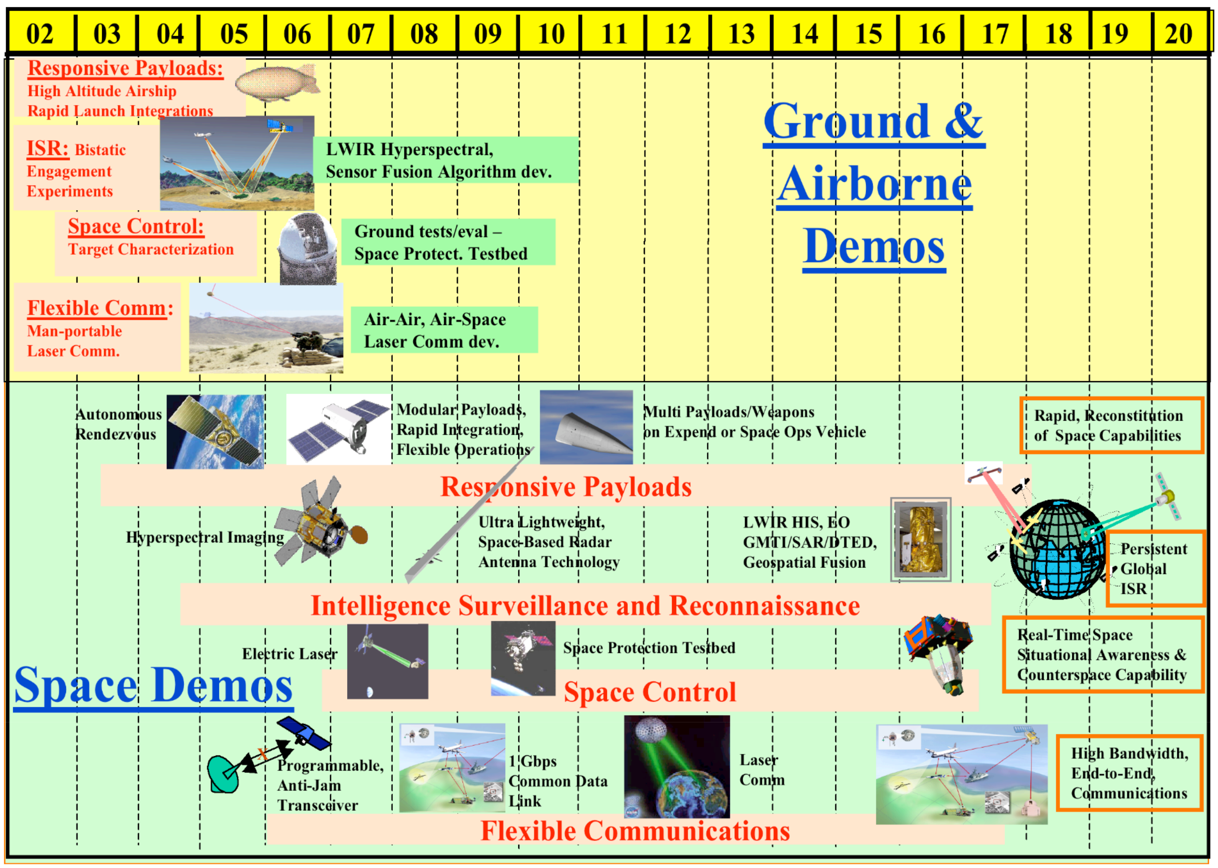

Figure 5
Space Technology (ST) Roadmap
(FY)

Current and Future Investments

The past decade has seen a number of breakthrough successes in the critical enabling technologies needed for the transformational capabilities NAI provides. In assessing our national investment, we have built on the work that has been performed over the years by researchers in such critical fields as propulsion, aerodynamics, high temperature materials, supersonic combustion, and computational fluid dynamics. For example, years of advanced research in turbine and ramjet technology have led to the recent successful ground demonstration of a hydrocarbon-fueled scramjet, which provides the critical step toward flight test of a hypersonic airbreathing propulsion system. These research successes are spawning currently planned flight demonstrations in this area, including the NASA Hydrogen-Fueled Scramjet Flight Test (Hyper-X), the Air Force Hydrocarbon Scramjet Program (HyTech), and the joint Navy/DARPA Hypersonic Flight Demonstrator Program (HyFLY). The results of these ground tests are available on request.

The DoD and NASA Basic and Applied Research (6.1/6.2) and Advanced Development (6.3) investments as submitted in the FY2004 President's Budget Request are consistent with the roadmaps and timelines shown above and provide the requisite funding needed to begin the near-, mid-, and far-term goals and objectives in the NAI plan. Approximately 38% of the combined FY2004 DoD/NASA NAI investment is in the basic and applied research areas, while ~62% of the combined investment is in technology demonstrations (for DoD-only, the percentages are 40% and 60%, respectively). It is vital that an aggressive and sustained basic (fundamental) and applied research investment be included in the outyear budget in order to provide the continuous flow of enabling technologies. The 40%/60% distribution between technology development and demonstration is viewed as prudent, but will be assessed annually based on progress toward the NAI goals to determine if adjustments are necessary. A review of currently programmed resources for FY 2005-2009 is underway within the Department and any required adjustments will be transmitted to the Congress with the FY2005 President's Budget Request.

Conclusions

NAI provides an integrated and balanced near-, mid-, and far-term technology development and demonstration approach for achieving its goals, which should enable a broad spectrum of future critical military capabilities. In FY04, NAI investments are split in reasonable proportion between basic/applied research and advanced technology demonstrations. The near-term flight demonstrations included within this budget submittal will provide empirical data for correlating both the theoretical predictive modeling/simulation and laboratory test results that preceded them. This information will provide the basis for future demonstrations, as well as a framework for defining future university and government laboratory research needs.

This report acknowledges that the US Air Force, while supportive of the NAI technology goals, has concerns regarding the aggressive schedule the NAI is attempting to achieve. The NAI team will continue to work with the Air Force to ensure that these concerns are addressed.

The NAI partnership of DoD, NASA, industry, and universities looks forward to working with the President and the Congress to sustain American Aerospace Leadership.

References

Reference 1: *Presidential Commission on the Future of the United States Aerospace Industry,* Final Report, November 2002

Reference 2: *Quadrennial Defense Review (QDR) Report,* Secretary of Defense Congressional response, September 2001

Reference 3: *Linking Science & Technology to Transformation*, Deputy, Secretary of Defense Congressional response, 1996

Reference 4: *The Nuclear Posture Review,* Congressional response, 2002

Reference 5: *America's Air Force: Global Vigilance, Reach and Power, Joint Vision 2020,* June 2000

Reference 6: *Why and Whither Hypersonics Research in the US Air Force,* Report published by the Air Force Scientific Advisory Board, 2000

Reference 7: *Committee on Review and Evaluation of the Air Force Hypersonic Technology Program,* National Research Council, 1998

Reference 8: *Military Spaceplane, Generating and Executing Combat Spacepower,* Results of the AF-NASA 120 Day Study on RLV, February 2002